EFFECT OF INDIUM ON MICROSTRUCTURE AND INTERMETALLIC COMPOUND FORMATION DURING ISOTHERMAL AGING OF SnCu SOLDER ALLOY

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by

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LIST OF ABBREVIATIONS

Ag	Argentum (silver)
Al	Aluminium
Au	Gold
BGA	Ball Grid Array
Bi	Bismuth
Cd	Cadmium
Ce	Cerium
Co	Cobalt
cm	Centimeter
CSPs	Chip scale packages
Cu	Copper
DIP	Dual In Line Package
DSC	Differential Scanning Calorimetry
EDX	Electron Dispersive X-ray Spectroscopy
Fe	Iron
g	gram (weight)
Ga	Gallium
Ge	Germanium
IC	Integrated circuit
IMC	Intermetallic Compound
In	Indium
kN	kilo Newton
mg	milligram
min	minute (time)

mm	milimeter (length)
Ni	Nickel
μm	micrometer
OSP	Organic solderability protection
P	Phosphorus
Pb	Plumbum
Pd	Palladium
Pt	Platinum
PTH	Pin Through Hole
PCB	Printed Circuit Board
PGA	Pin Grid Array
RA	Rosin activated
S	Sulphur
SAC	Sn-Ag-Cu
SAL	Sebatian Antara Logam
Sb	Antimony
SEM	Scanning Electron Microscopy
SMT	Surface Mount Technology
SN100C	Sn-0.7Cu-0.05Ni-Ge
SN100C-0.5In	Sn-0.7Cu-0.05Ni-0.5In
SN100C-1In	Sn-0.7Cu-0.05Ni-1In
SN100C-1.5In	Sn-0.7Cu-0.05Ni-1.5In
SN100C-2In	Sn-0.7Cu-0.05Ni-2In
Sn	Stanum (Tin)
SnCu	Tin-Copper

SnIn	Tin-Indium
SnPb	Tin-Lead
SnZn	Tin-Zinc
SnCuNi	Tin-Copper-Nickel
SnCuIn	Tin-Copper-Indium
SnAgCu	Tin-Silver-Copper
SnCuBi	Tin-Copper-Bismuth
Weight percent	wt.%
XRF	X-ray Fluorescent
Zn	Zinc

LIST OF SYMBOLS

A	Area
β-Sn	Sn-rich phase
d	IMC thickness after aging
d_o	Initial IMC thickness
D	Diffusion coefficient
D_o	Intrinsic Diffusivity
F	Wetting force
F_b	Buoyancy force
F_e	End force
F_{max}	Maximum wetting force
F_w	Withdrawal force
HV	Vickers hardness
J	Joule
m	meter
μ	micron
N	Newton
Q	Activation energy
R	Gas constant
S_b	Ratio of wetting force just before withdrawal to the wetting force during complete wetting
t	Aging time
t_1	Wetting time
T	Temperature
T_c	Crystallization temperature

T_m	Melting temperature
Θ	Wetting angle
γ	Surface tension of solder
γ_{sg}	Surface tension between solid and gas
γ_{sl}	Surface tension between solid and liquid
γ_{lg}	Surface tension between liquid and gas
^{o}C	Degree Celsius
%	Percentage
wt.%	Weight percent

KESAN INDIUM TERHADAP MIKROSTRUKTUR DAN PEMBENTUKAN SEBATIAN ANTARA LOGAM (SAL) SEMASA PENUAAN SESUHU KEPADA ALOI PATERI SnCu

ABSTRAK

Aloi pateri adalah bahan yang digunakan sebagai penyambungan elektronik dan mekanikal kepada komponen serta substrat dalam peralatan elektronik. Kebimbangan ke atas plumbum yang bertoksik mencetuskan fokus yang mendalam bagi mengenalpasti pateri bebas plumbum alternatif untuk menggantikan Pb-Sn aloi. Sn-Cu adalah satu calon yang menarik disebabkan ia mempunyai ciri fizikal, mekanikal dan kos yang rendah serta telah digunakan di dalam pematerian ombak. Walaubagaimanapun, aloi pateri Sn-Cu mempunyai takat lebur yang tinggi iaitu (227^{o}C) berbanding SnPb (183 ^{o}C). Dalam penyelidikan ini, Indium telah ditambah ke dalam Sn-0.7Cu-0.05Ni-Ge (SN100C) aloi pateri untuk mengurangkan takat lebur, tetapi kesan kepada pertumbuhan pembentukan sebatian antara logam (SAL) semasa penuaan sesuhu perlu dinilai. SN100C dan pertambahan indium (0.5, 1, 1.5 and 2 wt%) aloi telah disediakan dengan kaedah penuangan. Aloi pateri telah dipateri di atas substrat Cu pada suhu 270°C selama 10 saat. Komposisi aloi pateri ditentukan menggunakan analisis pendarfluor sinar-x (XRF) dan takat lebur aloi pateri ditentukan menggunakan kalorimeter imbasan kebezaan (DSC). Ujian kebolebasahan dan sebaran telah dijalankan untuk menganalisis kebolehbasahan. Manakala, penuaan sesuhu dilakukan selama 100, 250 dan 500 jam pada suhu 150°C dan 180°C. Mikrostruktur pateri pukal dan pembentukan SAL di lapisan antara muka telah diperhatikan menggunakan mikroskop imbasan elektron (SEM) yang dilengkapi dengan elektron sebar sinar-x (EDX). Kebolehbasahan bertambah dengan penambahan In.

Penambahan In selepas penuaan menghasilkan pembentukan SAL $(Cu,Ni)_6Sn_5$ and Cu_3Sn+Ni+In, pengurangan SAL Cu_6Sn_5 dan Cu_3Sn, sertapengecilan saiz dendrit β-Sn. Penambahan 2 wt.% In menyebabkan pembentukan SAL Sn-Cu-Ni-In. Penambahan In dalam aloi pateri memberikan kadar pertumbuhan SN100C-2In paling rendah iaitu 3.364 x 10^{-13} (cm^2/s) berbanding bagi sampel SN100C iaitu 4.096 x 10^{-13} (cm^2/s). Tenaga pengaktifan bagi SN100C-2In adalah tinggi iaitu 53 kJ/mol berbanding dengan SN100C iaitu 29.5 kJ/mol. Hasil daripada kajian, dapat disimpulkan kesan penambahan indium boleh memberi peranan kepada saiz ira β-Sn yang lebih halus, peningkatan kekerasan aloi pateri, kebolehbasahan yang meningkat serta lapisan Cu_3Sn SAL yang lebih nipis semasa penuaan sesuhu, dan ini dijangka dapat meningkatkan keboleharapan penyambungan aloi pateri.

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ABSTRACT

Solder is the interconnect material serving both electrical and mechanical connections between components and substrate in electronic devices. Concern over the toxicity of lead sparked intense focus on finding alternative lead-free solders to replace the traditional Sn-Pb solder. Among the lead-free solder alloy, Sn-Cu alloy has relatively good physical and mechanical characteristics, low cost, and is currently being used in wave soldering. However, Sn-0.7Cu solder alloy has higher melting point (227°C) compared to SnPb (183°C). Indium was added into Sn-0.7Cu-0.05Ni-Ge (SN100C) solder alloy in this work to reduce the melting point, but the effect to IMC growth during thermal aging need to be evaluated. SN100C and indium added (0.5, 1, 1.5 and 2 wt%) solder was prepared via casting process. The solder alloys were reflowed onto Cu substrate at 270°C for 10 seconds. Elemental composition was determined using X-ray fluorescence (XRF) technique while melting point of solder alloys was determined using differential scanning calorimetry (DSC). Wetting balance test and spreading test were used to evaluate wettability. Meanwhile thermal aging was done for 100, 250 and 500 hours at 150°C and 180°C. Respectively, the microstructure of bulk solder and the IMC formed at interface between solder and Cu substrate were observed using scanning electron microscopy (SEM) equipped with electron dispersive x-ray (EDX). The wettability of solder alloys increased with increasing amount of In. Addition of In after aging resulted in the formation of $(Cu,Ni)_6Sn_5$ and Cu_3Sn+Ni+In, seems to reduce formation of Cu_6Sn_5 and Cu_3Sn IMC, and refined primary β-Sn dendrites. Further addition of 2 wt.% In resulted in formation of Sn-Cu-

Ni-In IMC. The addition of 2 wt.% In gave the lowest growth rate of IMC which was 3.364×10^{-13} (cm^2/s) while SN100C gave highest growth rate at 4.096×10^{-13} (cm^2/s). The activation energy for SN100C-2In at 53 kJ/mol was the highest compared to SN100C 29.5 kJ/mol. From the result, it can be concluded that indium addition could lead to a finer β-Sn grain, increased hardness, improved wettability and supressed Cu_3Sn IMC layer during isothermal aging which could increase the reliability of solder joint.

CHAPTER ONE

INTRODUCTION

1.1 Research Background

Solder is a significant component in any electrical board or devices. Solder provides mechanical and electrical joint that is essential to keep components in place and the circuit is complete. While the mechanical strength is important to ensure the joint can last long, it is also necessary to ensure that the soldered joint provides a good electrical connection between the two components. This can only be achieved satisfactorily if the medium, i.e. the solder joining the two conducts electricity well. The soldering process is important in the realisation of all electronic products since the beginning of the electronic age, and it is anticipated that it will remain the primary assembly and interconnection technology (Loomans *et al.*, 1994) . Figure 1.1 shows the example of solder is used in typical flip chip bonding process.

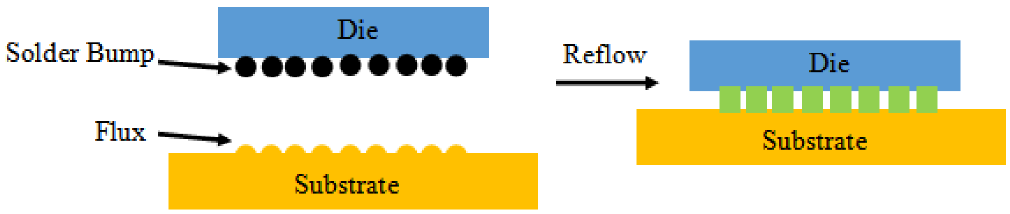

Figure 1.1: Typical flip chip bonding process (Freitas *et al.*, 2014).